

PRECISION POSITIONING DEVICE

Patent Application
of

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Docket No.: **W002.PAT-24**

PRECISION POSITIONING DEVICE

1 The present application is a continuation of pending provisional patent application
2 Serial No.60/414,751, filed on September 27, 2002, entitled "Precision Positioning
3 Device".

4 5 BACKGROUND OF THE INVENTION

6 1. Field of the Invention

7 This invention relates generally to a precision positioning device and, more
8 particularly, the invention relates to a precision positioning device which provides nesting
9 multi-stages (very coarse, coarse, fine, very fine, etc.), with each stage comprising a
10 parallel kinematic machine (PKM).

11 12 2. Description of the Prior Art

13 A number of precision applications require the ability to move quickly, over a
14 large dynamic range, in several directions, while withstanding failures. Consider a high
15 power telescope mounted on an aircraft. The telescope mount must move quickly to
16 cancel the aircraft vibrations and track out the aircraft motion. For high power
17 telescopes, it may need to maintain angular stability to nano-radian accuracy (billionths of
18 a radian), and be able to continue this accuracy across a dynamic range of a radian. The
19 telescope needs to rotate in at least two directions, and all six axes of motion affect image
20 quality.

21 22 SUMMARY

23 The present invention is a precision positioning device. The precision positioning
24 device comprises a precision measuring/vibration isolation mechanism. A first plate is
25 provided with the precision measuring mechanism or the item to be isolated secured to
26 the first plate. A second plate is secured to the first plate. A third plate is secured to the
27 second plate with the first plate being positioned between the second plate and the third
28 plate. A fourth plate is secured to the third plate with the second plate being positioned

1 between the third plate and the fourth plate. An adjusting mechanism for adjusting the
2 position of the first plate, the second plate, the third plate, and the fourth plate relative to
3 each other.

4 In addition, the present invention includes an apparatus for precision measuring.
5 The apparatus comprises a first plate group for extra fine positioning. A second plate
6 group is provided for fine positioning with the first plate group nested within the second
7 plate group. A third plate group is provided for course positioning and vibration isolation
8 with the second plate group nested within the third plate group. Adjusting means adjusts
9 the position of the first plate group, the second plate group, and the third plate group.

10 The present invention includes a method for precision measuring. The method
11 comprises providing a first plate group for extra fine positioning, providing a second plate
12 group for fine positioning, nesting the first plate group within the second plate group,
13 providing a third plate group for course positioning and vibration isolation, nesting the
14 second plate group within the third plate group, and adjusting the position of the first
15 plate group, the second plate group, and the third plate group.

16 17 BRIEF DESCRIPTION OF THE DRAWINGS

18 FIG. 1 a is a schematic view illustrating precision positioning device, constructed
19 in accordance with the present invention;

20 FIG. 2 is a plan view illustrating plate one of the precision positioning device,
21 constructed in accordance with the present invention;

22 FIG. 3 is a plan view illustrating plate two of the precision positioning device,
23 constructed in accordance with the present invention;

24 FIG. 4 is a plan view illustrating plate three of the precision positioning device,
25 constructed in accordance with the present invention;

26 FIG. 5 is a plan view illustrating plate four of the precision positioning device,
27 constructed in accordance with the present invention;

28 FIG. 6 is a side view illustrating post one of the precision positioning device,
29 constructed in accordance with the present invention;

1 FIG. 7 is a plan view illustrating post one of the precision positioning device,
2 constructed in accordance with the present invention;

3 FIG. 8 is a side view illustrating post two of the precision positioning device,
4 constructed in accordance with the present invention;

5 FIG. 9 is a plan view illustrating post two of the precision positioning device,
6 constructed in accordance with the present invention;

7 FIG. 10 is a schematic view illustrating the precision positioning device,
8 constructed in accordance with the present invention, with the stages nested to produce a
9 compact device with a low center of gravity resulting in higher performance and ability to
10 fit in tight locations;

11 FIG. 11 is a perspective view illustrating an embodiment of the precision
12 positioning device, constructed in accordance with the present invention, with the struts
13 for the two inner stages assembled and four legs used for each stage to add fault
14 tolerance;

15 FIG. 12 is a perspective view illustrating the embodiment of the precision
16 positioning device of FIG. 11, constructed in accordance with the present invention, with
17 a high speed camera added as the payload;

18 FIG. 13 is a perspective view illustrating the embodiment of the precision
19 positioning device of FIG. 11, constructed in accordance with the present invention, with
20 the device fully assembled with a passive vibration isolation outer stage and two active
21 inner stages; and

22 FIG. 14 is a top perspective view illustrating the embodiment of the precision
23 positioning device of FIG. 11, constructed in accordance with the present invention.
24

25 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

26 As illustrated in FIGS. 1 – 14, the present invention is a precision positioning
27 device, indicated generally at 10, which provides nesting multi-stages (very coarse,
28 coarse, fine, very fine, etc.), with each stage comprising a parallel kinematic machine
29 (PKM). The precision positioning device can move in full six degree-of-freedom (DOF)

1 applications with the initial device being designed to move in three DOF (translate in z,
2 rotate in x and y).

3 The precision positioning device 10 of the present invention includes a first plate
4 12, a second plate 14, a third plate 16, and a fourth plate 18. The first plate 12 is
5 connected to the second plate 14, the second plate 14 is connected to the third plate 16,
6 and the third plate 16 is connected to the fourth plate 16. Connection of the plates 12, 14,
7 16, and 18 to each other will be discussed in further detail below.

8 Furthermore, as illustrated, the first plate 12 and the second plate 14 form a first
9 nesting group 20, the second plate 14 and the third plate 16 form a second nesting group
10 22, and the third plate 16 and the fourth plate 18 form a third nesting group 24.

11 As illustrated in FIG. 2, the first plate includes a center portion 26 having an inner
12 annular aperture with a radius of approximately 2.2 inches and four ears 28 extending
13 from the center portion 26. Through holes 30 are formed in the center portion 26 at a
14 distance of approximately 2.9 inches from a center point of the first plate 12. Beveled
15 through holes 32 are also formed in each ear 28 at a distance of approximately 5.3 inches
16 from the center point of the first plate 12. The diameter of the first plate 12 at the outer
17 edge 34 of the ears is preferably approximately 6.2 inches. The thickness of the first plate
18 12 is preferably approximately 0.5 inch.

19 As illustrated in FIG. 3, the second plate 14 includes a plurality of cutouts 36
20 having a length of approximately 1.2 inches and a width of approximately 1.2 inches. A
21 threaded through hole 38 is formed in the second plate 14 at a center point and a plurality
22 of beveled through holes 40 are formed in the second plate 14 at a distance of
23 approximately 5.3 inches from the center point of the second plate 14. Preferably, there
24 are two beveled through holes 40 between each cutout 36 with a spacing of 30°, although
25 more beveled through holes 40 or less beveled through holes 40 are within the scope of
26 the present invention. Furthermore, the diameter of the second plate 14 is preferably
27 approximately 6.2 inches and the thickness is preferably approximately 0.5 inch.

28 As illustrated in FIG. 4, the third plate 16 has an inner diameter of preferably
29 approximately 3.6 inches and an outer diameter of preferably approximately 6.2 inches.

1 The third plate 16 includes a plurality of threaded through holes 42 formed in the third
2 plate 16 at a distance of approximately 5.3 inches from a center point of the third plate 16.
3 A plurality of beveled through holes 44 are also formed in the third plate 14 at a distance
4 of approximately 5.3 inches from the center point of the third plate 14. Furthermore, the
5 third plate 14 has a thickness of preferably approximately 0.5 inch.

6 As illustrated in FIG. 5, the fourth plate 18 includes a threaded through hole 46 at
7 a center point of the fourth plate 18. In addition, other threaded through holes 48 are
8 formed in the fourth plate 18 with each other threaded through hole 48 being
9 approximately 3.0 inches apart from each other. Beveled through holes 50 are formed in
10 the fourth plate 18 at a distance of approximately 5.3 inches from the center point of the
11 fourth plate 18 with each beveled through hole 50 being approximately 90° from each
12 other. Furthermore, the diameter of the fourth plate 18 is preferably approximately 6.2
13 inches and the thickness is preferably approximately 0.5 inch.

14 It should be noted that while certain dimensions and thicknesses are provided for
15 the first plate 12, the second plate 14, the third plate 16, and the fourth plate 18, the
16 person skilled in the art will understand that these dimensions and thicknesses are for
17 illustrative purposes only and other dimensions and thicknesses are within the scope of
18 the present invention. Furthermore, while the positioning of the beveled through holes
19 and threaded through holes on each of the plates 12, 14, 16, and 18, respectively, have
20 been set forth at a certain distance from the center point, it is within the scope of the
21 present invention to form the beveled through holes and threaded through holes at various
22 different distances from the center point of each of the plates 12, 14, 16, and 18 so long as
23 the appropriate beveled through holes and the threaded through holes are aligned for
24 receiving the legs 52. The alignment of the beveled through holes and the threaded
25 through holes for receiving the legs 52 are illustrated in the drawings.

26 Each three DOF PKM stage consists of three or four legs 52, with each leg 52
27 having a linear actuator 54 or the like to change each leg's length. In addition, each leg
28 52 has a rotation joint 56 at each end in addition to the linear actuator 54. For a three leg
29 PKM, the legs 52 would preferably be separated by 120°, thus forming a three-leg table.

1 For a four leg PKM, the legs 52 would be preferably separated by 90°. The three DOF
2 PKM nests together to save space and improve the dynamic response of the precision
3 positioning device 10.

4 The nested design of the precision positioning device 10 of the present invention
5 allows multi-stage performance in a small package. The addition of a fourth leg 52 per
6 stage allows very high levels of fault tolerance.

7 Furthermore, the precision positioning device 10 of the present invention can be
8 accommodated within volumes not possible with alternative technology, and have high
9 dynamic performance because of a low center of gravity. This is essential for retrofits, as
10 well as mobile platforms.

11 As understood by those persons skilled in the art, the drawings illustrate one
12 embodiment of the precision positioning device 10 of the invention designed specifically
13 for precision pointing and vibration isolation of a CCD camera 58 (or other sensitive
14 scientific instrument). Such a unit would be especially useful for air and space based
15 reconnaissance or mapping systems. For this particular application, the legs 52 have a
16 rotary flexure joint 56 at each end and a PZT actuator in the middle (model P-843.60 Pre-
17 loaded PZT translator manufactured by PI Polytec Co.). For the middle (fine) stage,
18 standoff posts (Fig. 6) are used to increase the overall length of the legs. For the outer
19 (coarse) stage, a post (Fig. 8) is connected to a passive, elastomeric absorber. The legs 52
20 are bolted to the plates 12, 14, 16, and 18, as illustrated (Fig. 10-14). Based on sensor
21 measurements from the CCD camera 58 and accelerometers 60, the leg 52 lengths are
22 then controlled to minimize the adverse effects of vibrations and have the camera track
23 objects.

24 Precision positioning and vibration isolation are important in a number of
25 aerospace, military, and manufacturing applications. As miniaturization proceeds in
26 manufacturing, this technology is expected to grow in importance. For instance, the
27 ambient seismic vibrations in a semi-conductor foundry are becoming increasingly
28 problematic. The precision positioning device 10 of the present invention provides a way
29 of mitigating the negative effects of these vibrations. Similar problems occur in a variety

1 of scientific instruments including scanning electron microscopes, scanning tunneling
2 microscopes, atomic force microscopes, and gravity wave detectors. Aerospace
3 applications include high-resolution mapping, vibration isolation for news helicopters
4 (both for cameras and crew) and police helicopter camera isolation. Other applications
5 include isolation of ambulance (ground or air-based) vibrations, especially for patients.
6 For these purely vibration isolation applications that do not require any position
7 measurement, the CCD camera would not be necessary. Instead, for instance, the present
8 invention would form a leg of a stretcher, and the stretcher would be attached where the
9 CCD is shown.

10 The foregoing exemplary descriptions and the illustrative preferred embodiments
11 of the present invention have been explained in the drawings and described in detail, with
12 varying modifications and alternative embodiments being taught. While the invention
13 has been so shown, described and illustrated, it should be understood by those skilled in
14 the art that equivalent changes in form and detail may be made therein without departing
15 from the true spirit and scope of the invention, and that the scope of the present invention
16 is to be limited only to the claims except as precluded by the prior art. Moreover, the
17 invention as disclosed herein, may be suitably practiced in the absence of the specific
18 elements which are disclosed herein.